Properties and Classifications of Matter

PS-3 The student will demonstrate an understanding of various properties and classifications of matter.

PS-3.5 Explain the effects of temperature, particle size, and agitation on the rate at which a solid dissolves in a liquid.

Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:

Kinetic Theory
Temperature (effect on particle motion)
Particle size (effect on surface area)
Agitation (effect on solute/solvent collisions)

Previous/Future knowledge: In 5th grade (5-4.6) students explained how temperature change and stirring affect the rate of dissolving, but at this point students are only required to understand that these factors do have an affect on the rate of dissolving, not why. 5th grade students were introduced to the particulate nature of matter (5-4.1). In 7th grade students recognized that matter is composed of extremely small particles called atoms (7-5.1).
Indicator PS-3.4 introduced Physical Science students to a solution as a homogeneous mixture in which the components are close to the size of individual particles of the substance (atoms, molecules, or ions) and, therefore, too tiny to be seen with a microscope.

It is essential for students to

- Understand the three basic assumptions of kinetic theory.
  - All matter is composed of small particles (molecules, atoms, and ions).
  - The particles are in constant, random motion.
  - The particles are colliding with each other and the wall of their container.
- Understand the process of dissolving in terms of the kinetic theory.
  - The solvent (in this case water) is composed of individual water molecules (H_2O), all close enough to touch, but in constant motion, moving over, under, and past one another. (see liquids PS-3.6)
  - The solute (such as table sugar) is composed of crystals.
    - Each crystal is composed of billions of individual sugar molecules. The individual molecules are attracted to each other (not chemically bonded) together. The sugar molecules in the crystal are also moving but because sugar is a solid (See PS-3.6) the molecules do not move past each other, they vibrate in place.
    - Because sugar is a molecular compound, the individual sugar molecules can not be decomposed by a physical process such as dissolving, so the dissolved sugar remains as sugar molecules and not separated carbon, hydrogen and oxygen atoms.
    - The dissolving process involves the sugar molecules being pulled away from each other by the water molecules but each molecule of sugar remains intact.
    - The sugar molecules on the surface of the crystal are the only ones to dissolve because they are the ones in contact with the water molecules. As surface sugar molecules dissolve, they expose the ones beneath to the water.
    - Because the dissolved sugar molecules are surrounded by water molecules, they are not attracted to each other (the water molecules block the attractive force).
    - In the resulting solution, the sugar molecules are distributed throughout the water.

    - The water can be removed by boiling the water or allowing it to evaporate. When the water boils or evaporates away, the sugar molecules will once again be attracted to each other and sugar crystals will reform.
- Understand how temperature affects the rate at which substances dissolve.
    - The higher the temperature, the faster the rate of dissolving for a solid in a liquid.
    - At higher temperatures more of the solvent molecules are moving faster and collisions with the surface of the solute occur more often carrying off particles of the solute so dissolving occurs more rapidly.
- Understand how particle size affects the rate at which substances dissolve. (Are they large chunks of material or ground into many small pieces as in a powder?)
    - The smaller the size of the pieces of solute, the faster they dissolve.
    - The smaller the size of the individual pieces, the more surface area the sample will have to be in contact with the water molecules. With more surface area in contact the water molecules, the water will have more opportunities to pull the solute molecules away from the solute's surface, thereby, dissolving it faster.
- Understand how agitation affects the rate at which substances dissolve.
    - The more the solution is agitated, the faster the rate of dissolving for a solid in a liquid.
    - When a solution is agitated, the water particles collide with the surface of the solute more frequently and the dissolving process occurs faster.
- Understand that if a substance is soluble in water, it will eventually dissolve even if the size of the sample pieces of solute are large, the temperature is low and there is no agitation.

Misconception: Students often confuse rate of dissolving (how fast a substance dissolves) with solubility (what quantity of a substance can dissolve) (see PS-3.1).

It is not essential for students to
- Understand the intermolecular forces within a molecular crystal;
- Understand the energy of solution;
- Understand the polar nature of the water molecule;
- Differentiate polar and non-polar solvents.

Assessment Guidelines:
The objective of this indicator is to *explain* the effects of temperature, particle size, and agitation on rate of dissolving, therefore, the primary focus of assessment should be to construct cause and effect models based on kinetic theory that show the effect each variable has on the rate of dissolving. The cause and effect here is not "the solute dissolves faster because the particle size is smaller" but rather "smaller particle size increases the rate of dissolving because when a substance is in smaller pieces, there is more surface area exposed to collide with the solute molecules."

In addition to *explain*, assessments may require that students
- *Compare* the dissolving rate of solutions that differ according to one of the indicator variables;
- *Summarize* the effect of the factors influencing the rate of dissolving; or
- *Recall* the effect of the indicator variables on the dissolving process.